GASP! The Response of Marine Fishes to Water with Low Dissolved Oxygen in Southern Hood Canal, Washington

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The southern portion of Hood Canal is at the head of a long narrow fjord and has been plagued by low dissolved oxygen (DO) concentrations that have worsened during 2002 and 2003. There marine reserves are coincidently located in the southern half of Hood Canal at Sund Rocks, Octopus Hole, and Waketickeh Creek. The Washington Department of Fish and Wildlife (WDFW) has intensively monitored Sund Rocks for patterns of fish abundance and size of key species of rockfishes (*Sebastes* spp.), lingcod (*Ophiodon* elongatus), and wolf-eel (Anarrichthys ocellatus) for specific responses to the creation of the reserves. However, these studies preposition WDFW scientists to examine the response of these species to low DO conditions. We specifically evaluated behavioral responses and lethality to oxygen concentrations typically less than 4 ml/l and less than 2 ml/l under certain conditions.

Scuba surveys provided the basis to test for changes in abundance and distribution patterns of rockfishes and other marine species during and after low DO events at the Sund Rocks Conservation Area. Beginning in the Fall 2001, two divers conducted censuses of larger marine fishes by distinct depth zones at two rocky outcrops. Underwater buoys and depth gauges were used to locate specific underwater features and divide the rocky habitat by five depth zones including two deeper than 10 m (mean low low water) and three from the shoreline to 10 m in depth. Key fishes were identified to species, measured to the nearest 10 cm with the aide of rulers, and tallied on underwater forms. One census was conducted at the north and south site in Fall 2001 and two were conducted during subsequent Novembers in 2002 to 2004. The censuses were repeated on an opportunistic basis during October 2002 and 2003 and in September 2003 and 2004 when unusual fish behaviors or mortalities were observed. During the one observed mortality event, dead rockfishes were recovered from the beach, identified, and measured and other dead marine species were noted. Fish observations were compared to the nearest and most recent observations of low dissolved oxygen made by the Washington Department of Ecology's Marine Water Quality Monitoring Program, the University of Washington's PRISM program, and the Hood Canal Spawning Enhancement Group.

Copper rockfish (*Sebastes caurinus*) was the best species to characterize the DO response of most marine fishes at Sund Rocks. During the November sampling periods, DO concentrations were greater than 2 mg/l and typically at least 4 mg/l. During these periods, copper rockfish were distributed between depths from 7 m to 21 m among the available rocky habitats. With the onset of low DO conditions during October 2002,

September 2003, and September 2004, the 2 mg/l oxygen water rose from deeper depths to the 17 m to 21 m depth zone. During these periods, copper rockfish became concentrated near the shoreline and at the surface in depths of 9 m or less. Once DO conditions improved and approached 4 mg/l in subsequent Novembers, the fishes reoccupied their normal depth distribution. This pattern was observed during three years of study, but was found to be even more extreme in October 2003 when fish were concentrated in dense schools near the surface and shoreline. During the event, the 2 mg/l DO zone was near the surface, and virtually all of the copper rockfish were in less than 6 m depth along the shoreline and almost all were in the southern study area. By November 2003, the copper rockfish had resumed their normal depth distribution from 7 m to 21 m and the 4 mg/l DO zone was near the deepest part of the rocky habitat.

The October 2003 survey corresponded to a mass mortality event. Twenty-six species of marine fishes were found dead on the beach at Sund Rocks or in the nearby subtidal zone. The mortalities included approximately 100 copper rockfish, most of which were collected from the exposed intertidal rocks. The sizes of the dead copper rockfish principally ranged from 20 cm to 30 cm while the surviving fish underwater were mostly in the 30 cm and 40 cm size categories. Censuses after the mortality event averaged one third lower than the population sizes prior to October 2003 and the difference in population was approximately 125 individual copper rockfish, suggesting that we observed the majority of the fish mortalities in the field.

The observed response and susceptibility of marine fishes to low DO provides the basis to predict the impacts of worsening water quality and the efficacy of locating marine reserves in oxygen depleted areas. Copper rockfish appear to avoid and cannot tolerate DO conditions of 2 mg/l or less. They apparently avoid this concentration by moving to shallow waters that are slightly higher in dissolved oxygen concentrations. They can quickly respond to improved oxygen conditions and reoccupy their usual, deeper habitats. The population sizes do not decrease during most low DO events. However, unusual conditions that upwell the low DO layers can cause mass mortality events that impact smaller individuals.

If DO conditions continue to worsen in southern Hood Canal, rockfish and other marine species may be able make limited vertical and horizontal movements to avoid poor water quality. However, these responses may be limited when sustained low DO concentrations are prevalent and may ultimately eliminate suitable habitat in southern Hood Canal, negating the positive impacts of marine reserves and substantially altering productivity and ecosystem vitality.